NASA-CR-161083

(NASA-CR-161083) RFI SIMULATION DEFINITION STUDY, EXHIBIT D Final Report (LinCom Corp., Pasadena, Calif.) 23 p HC A02/MF A01 CSCL 20N

N81-32346

Unclas

G3/32 27461

LinCom Corporation

P.O. Box 2793D, Pasadena, Calif. 91105

LinCom

FINAL REPORT

RFI SIMULATION DEFINITION STUDY

EXHIBIT D

PREPARED FOR

NASA LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TX 77058

TECHNICAL MONITOR: MELVIN H. KAPELL

CONTRACT NO. NAS9-15799

PREPARED BY

W. R. BRAUN

LINCOM CORPORATION
P.O. BOX 2793D
PASADENA, CA 91105

SEPTEMBER 1, 1981

TR-0982-1179-200

LinCom

TABLE OF CONTENTS

LinCom

LIST OF FIGURES

LinCom

LIST OF TABLES

1. Introduction

1.1 Overview

This document represents the final report on the RFI Simulation Definition Study performed for Johnson Space Center under Contract NAS9-15799 directed by Melvin H. Kapell. It represents a portion of the work accomplished during the reporting period 30 January 1980 through 1 September 1981.

The objective of this contract was to define specifications, recommend ESTL test requirements and perform comparative analyses of experimental and predicted effects of the radio frequency interference (RFI) environment on the Shuttle/TDRSS S-band links.

This section provides an overview of the tasks performed under this contract. The remaining sections contain procedures for using the RFI test generator in the ESTL S-band link tests and provide performance predictions for these links in the RFI environment.

1.2 Report Contents

This report documents LinCom's effort to provide the five deliverable items called for in the Statement of Work.

Item A. Required the submission of a specifications document for the ESTL RFI simulator. This document was submitted and presented to ESTL personnel on February 11, 1980. In addition, LinCom personnel participated in the review and editing of the final

joint GSFC/JSC RFI Test generator specification which was the basis for the procurement of two units from Harris Government Communications Systems Division.

Item B. Requires LinCom to coordinate with Electronic Systems Laboratory (ESL) personnel to insure RFI simulator specifications are compatible with the GSFC/ESTL RFI environment assessment. LinCom determined that the RFI simulator implementation meets JSC/ESTL test requirements and simulator specifications. In addition, LinCom insured that the RFI test generator design provides enough flexibility to accommodate future updates of the predicted RFI environment.

Item C. Requires LinCom to submit a report which includes ESTL RFI test equirements and test predictions. These data are provided in Section 5 of this report.

Item D. Calls for LinCom to provide technical support at the RFI simulator preliminary and critical hardware design reviews. LinCom personnel were present at these meetings, evaluated the design and test documents and reported the findings to the technical officer during informal meetings and in memoranda.

Item E. Requires LinCom to submit a report comparing the ESTL test results with predicted performance. Due to the lack of experimental data at the end of the contract, a careful evaluation of the ESTL test procedures is provided in Section 2 of this report.

This will ensure that a major difference between measured and computed performance data will not occur and obviate the need for such an analysis.

2. Proposed ESTL Test Setup and Calibration

The proposed ESTL test setup is shown in Fig. 1. The signal from the RFI test generator (RTG) is summed with the Shuttle simulator signal at the input of the preamplifier in the TDRS simuulator. The variation of the TDRS antenna gain in the direction of the RFI sources can be modeled by either using the RTG internal programmable attenuator or by using an external attenuator between the RTG and the signal combiner. The latter approach will be considered below.

It is assumed that the RTG has been calibrated in accordance with the procedures given in the RTG manual. This includes:

-setting the minimum and maximum CW frequency of the type A pulses

-setting the minimum pulse power level to -70 dBm for type A and B signals

-setting the pulse power level to 0 dBm for the type C signal.

The calibration procedure then follows the steps outlined in Table 1. Note that Steps 1, 2, and 3 should agree with the present non-RFI test procedures. The only value required for RFI calibration is the noise spectral density N_0 at the input to the preamplifier.

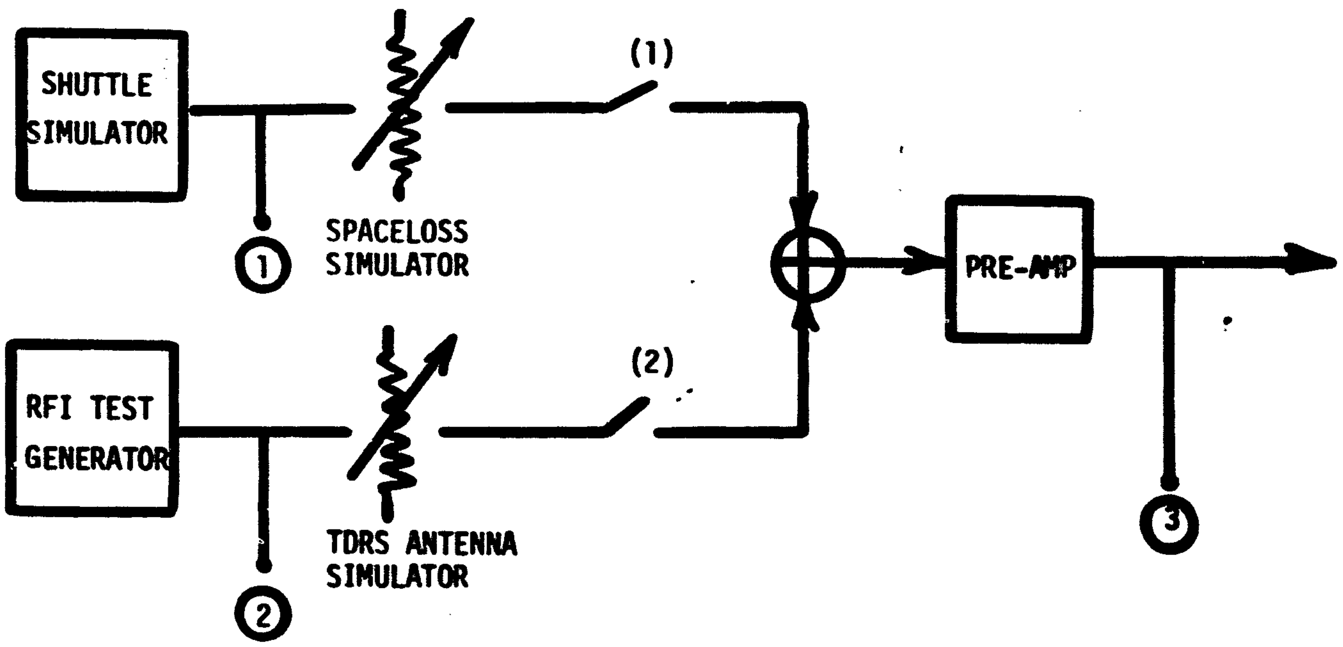

Figure 1. ESTL RFI TEST SETUP.

Table I. RFI TEST SETUP CALIBRATION.

1. Turn off Shuttle simulator and RFI Test Generator (RTG) outputs. Measure noise power level at 3 .
2. Compute noise spectral density N_0 at input to preamp.
3. Turn on Shuttle simulator output. Measure signal power at 1 . Set spaceloss simulator for desired C/N_0 at preamp input.
4. Set the RTG minimum amplitude to -70 dBm.
5. Set TDRS antenna simulation attenuator to $(-166.1-N_0)$ dB, where N_0 is the measured one-sided noise spectral density in dBW/Hz.
6. This setting is valid for the TDRS antenna pointing directly to the RFI region. Increase the attenuator setting to simulate offpointing as follows:

   1.5 deg offpointing: 12 dB

   4.0 deg offpointing: 24 dB

The setting of the RFI path attenuator is computed in Table 2 as a function of the low noise amplifier (LNA) noise power spectral density. Table 3 shows how the thermal noise power and the RFI power can be compared.

Since the highest EIRP levels to be simulated with type C pulses are approximately 100 dBW and the reference EIRP level for type a and b signals is 20 dBw, it must be possible to set the high amplitude CW power level 80 dB higher than the reference power level. Since the highest setting for type C signals is 0 dBm, the type A and B reference level at the RTG output should be reduced to -80 dBm whenever type C signals are used. Accordingly, the attenuation setting of the attenuator between RTG and signal combiner should be reduced by 10 dB.

3. RFI Tests

This section outlines the RFI environments which should be simulated for the testing of the Shuttle S-band links. For each environment, the same tests should be performed as are used for the non-RFI links (BER, acquisition, etc.).

The basic RFI tests should be performed without the high-power pulses. Then, the high power RFI can be added to verify that no serious performance degradation occurs with this kind of interference.

The presently modeled RFI environments are shown in Figures 2 to 5. The available RFI data show that short and long pulses (2 and 5μsec, respectively) with the long

Table 2. Computation of Attenuator Setting.

TDRS N_0 = -201.086 dBW/Hz

CORRESPONDS TO

NOISE POWER IN 20 MHz P_n = -128.08 dBW

CORRESPONDS TO

EQUIVALENT EIRP = 26.86 dBW

SO

RFI EIRP = 20 dBW (REFERENCE LEVEL)

CORRESPONDS TO

RFI POWER P_I = -128.08-6.86 dBW = -134.94 dBW

= -104.94 dBm

SO

ATTENUATOR SETTING FOR TDRS LNA

a = -70 dBm + 134.94 dBW = 34.94 dB

FOR LNA WITH NOISE PSD N_0'

$$a' = a + N_0 - N_0'$$

$$= -166.146 \text{ dBW/Hz} - N_0'$$

Table 3. Computation of Equivalent EIRP for Thermal Noise

TDRS NOISE TEMPERATURE T = 564 ^{o}K (TPM 6/80, p.43)

REF. NOISE BANDWIDTH = B_n = 20 MHz

N_0 = KT = -201.086 dBW/Hz

P_n = N_0B_n = -128.08 dBW

= - 98.09 dBm

SPACE LOSS = 192.2 dB (TDRSS USERS' GUIDE, P. A-9)

ANTENNA GAIN = 37.26 dBI

EQUIVALENT EIRP FOR P_n = 56.86 dBm

= 26.86 dBW

pulses dominating at the higher EIRP levels, see Table 4. It is therefore a good approximation to use a 5 μsec pulse duration for the RFI tests.

The proposed RFI test matrix is shown in Table 5. All these tests are performed without the high amplitude CW pulses.

In order to test the system susceptibility to high power pulses outside the channel bandwidth, the high amplitude CW pulses may be added in a second phase of the RFI tests. This simulates the event of one or more radars with pulse EIRP's of approximately 100 dBW pointing directly at the TDRS. The RFI studies give no guidance as to the probability of such an occurrence, hence educated guesses will have to be used to find reasonable settings. The tests proposed in Table 6 are based on the assumption that such high-powered radars can only have a very low duty cycle.

4. Updated RFI Environments

In June of 1980, a new set of RFI environments was published [1]. As Figures 2 through 5 show, they do not differ significantly from the environments presently implemented in the RTG. Some of them have higher pulse rates at the low power end, but most of them have either the same or lower pulse rates at the higher power levels. The overall system performance can, therefore, be expected to be approximately the same under both environments and an immediate reprogramming of the RTG is

TABLE 4.
SIMPLIFIED ("TEST") ENVIRONMENT:
MODERATE OR TYPICAL RFI FOR SSA

dBW	PPS 5 μsec PULSES	PPS 2 μsec PULSES	DUTY CYCLE (PERCENT)	SIGNAL TYPE
20	3600	26200	7.0	Noise
30	12500	23700	11.0	Noise
40	7300	3700	4.4	Noise
50	4100	600	2.2	CW
60	3150	250	1.6	CW
≥70	400	175	.24	CW
100	2	N/A		CW

Table 5. RFI Test Matrix.

RFI ENV #	CENTER FREQ. MHz	PULSE WIDTH μsec	MIN AMPLITUDE dBm	ANTENNA OFFPOINTING deg	CARRIER FREQUENCY MHz	HIGH AMPLITUDE CW PRF (PPS)
1	2287	5	-70	0	2287.5	0
1	2287	5	-70	1.5	2287.5	0
1	2287	5	-70	4.0	2287.5	0
2	2217	5	-70	0	2217.5	0
2	2217	5	-70	1.5	2217.5	0
2	2217	5	-70	4.0	2217.5	0
3	2287	5	-70	0	2287.5	0
3	2287	5	-70	1.5	2287.5	0
3	2287	5	-70	4.0	2287.5	0
4	2217	5	-70	0	2217.5	0
4	2217	5	-70	1.5	2217.5	0
4	2217	5	-70	4.0	2217.5	0

Table 6. Tests for High Power RFI Effects.

OFFSET FROM CENTER FREQUENCY (MHz)	AMPLITUDE (dBm)	PULSE/ SEC	PULSE WIDTH (μsec)
20	0	10	5
40	0	20	5
60	0	30	5

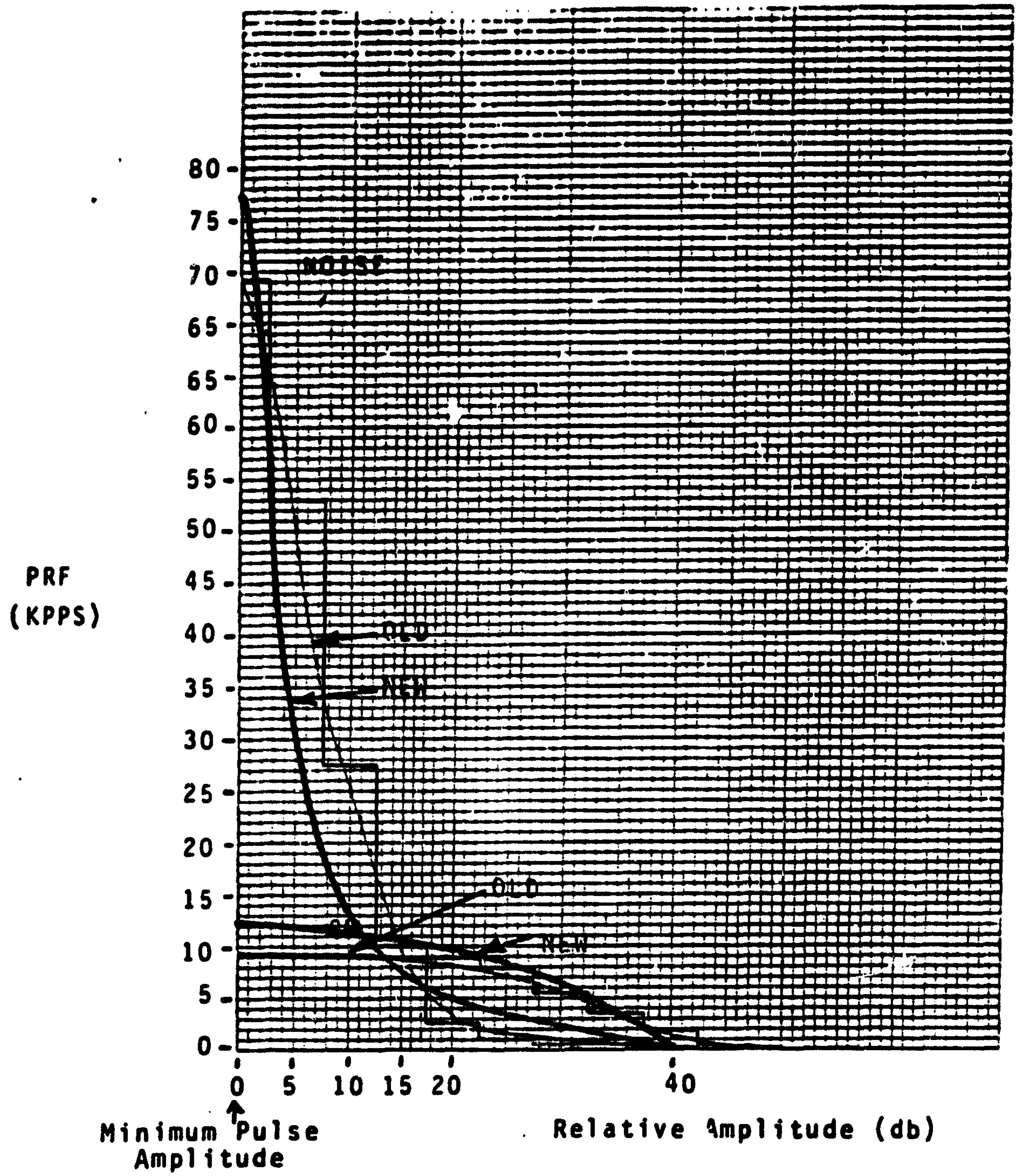

Figure 2. COMPARISON OF OLD AND NEW RFI ENVIRONMENT 1 (EH).

ORIGINAL PAGE IS
OF POOR QUALITY

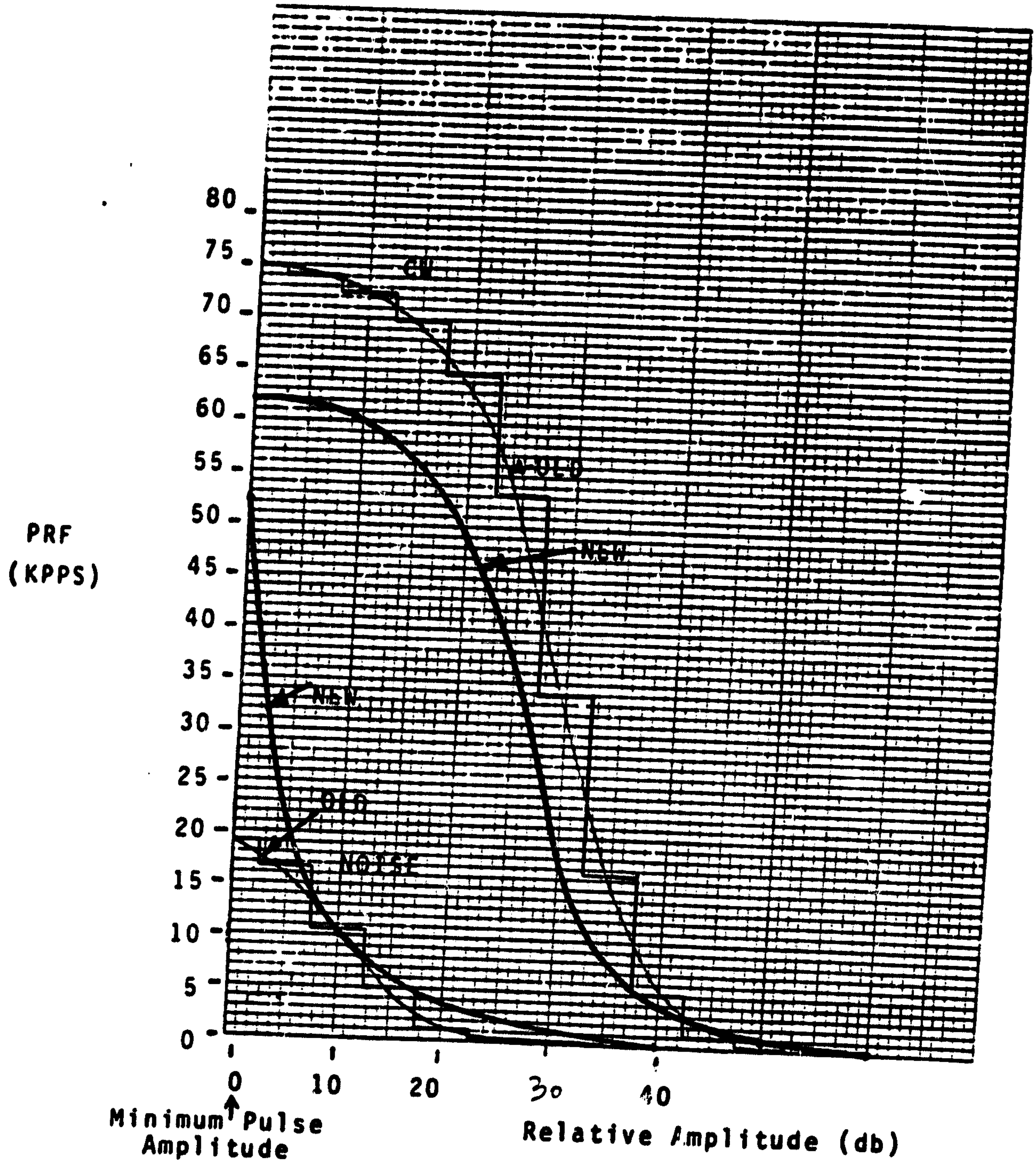

Figure 3. COMPARISON OF OLD AND NEW RFI ENVIRONMENT 2 (EL).

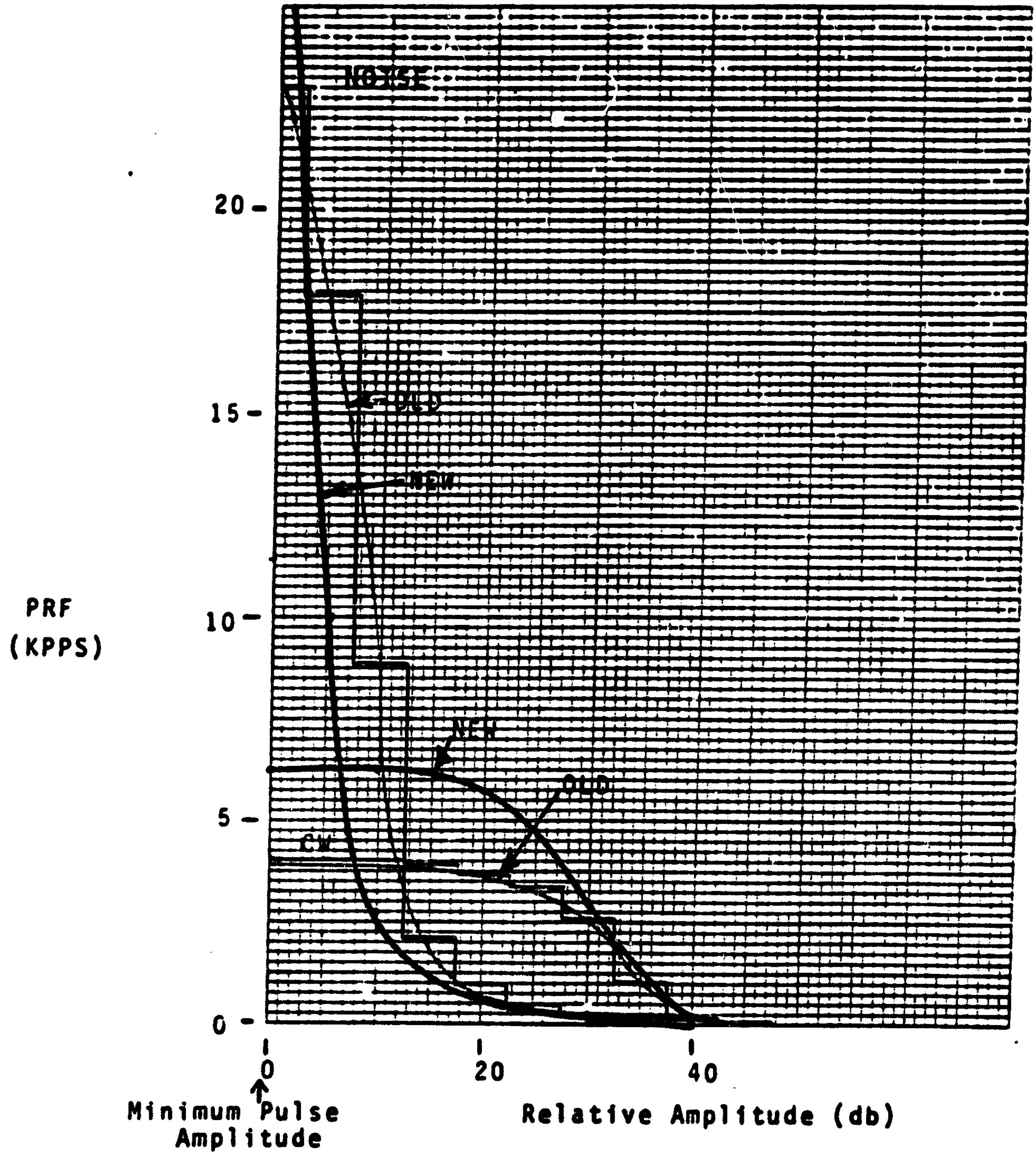

Figure 4. COMPARISON OF OLD AND NEW RFI ENVIRONMENT 3 (WH).

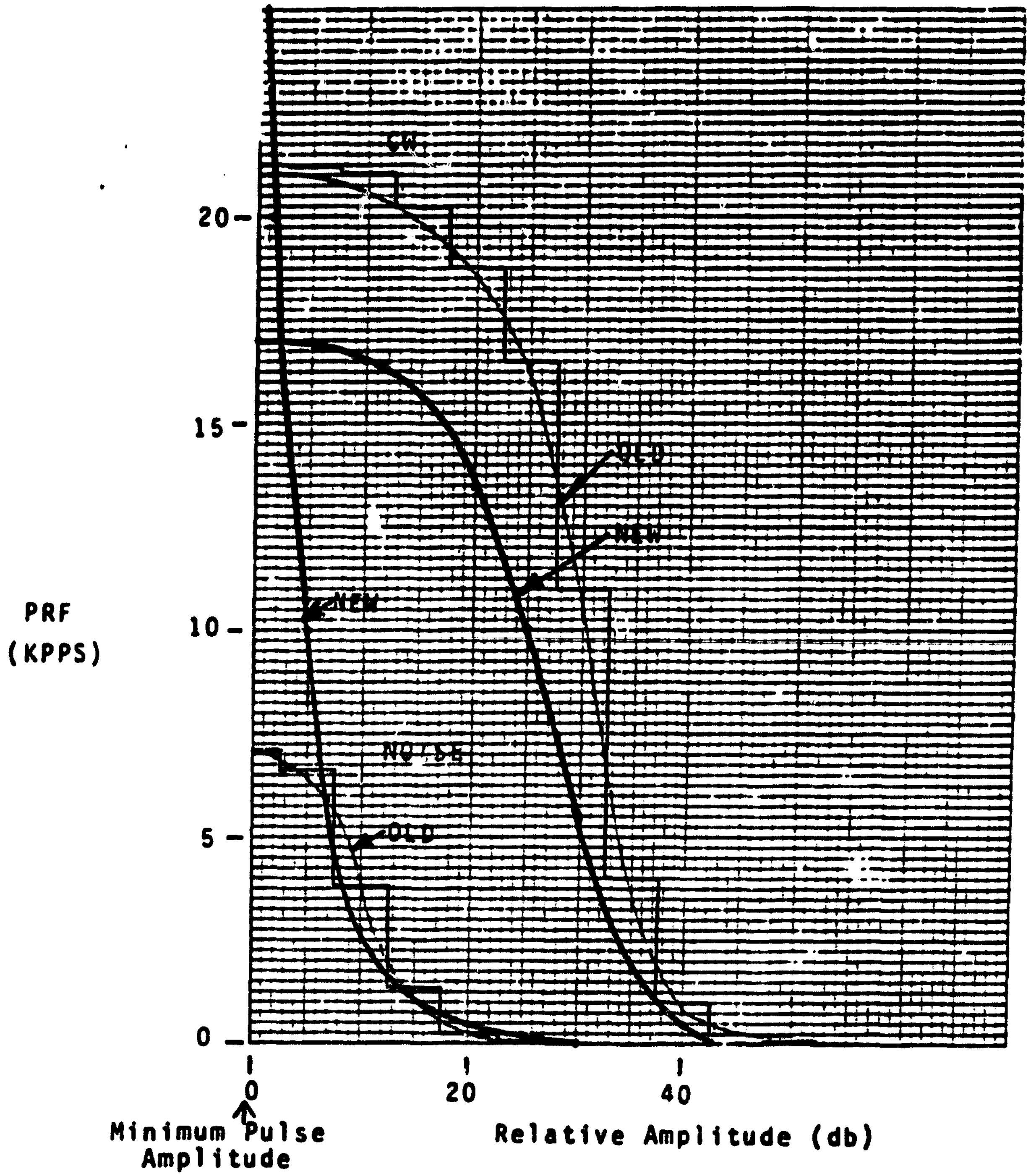

Figure 5. COMPARISON OF OLD AND NEW RFI ENVIRONMENT 4 (WL).

ORIGINAL PAGE IS
OF POOR QUALITY

not warranted.

5. Prediction of RFI Performance Degradations

The bit error rate performance degradations resulting from the RFI environments presently modeled in the RTG firmware was evaluated with the LinCsim software package. It was found that the effect of the high-power RFI pulses is very sensitive to hardware parameters, such as amplifier saturation effects, for which no measured characteristics were available. The results presented below are for this reason based on type A and B pulses only.

For the performance evaluation, the link power was adjusted to -yield a bit error probability of exactly 10^{-4} without RFI. Then, RFI was added and the linnk power was increased until the bit error probability stood at 10^{-4} again. This increase in power is the reported BER performance degradation. The reference power level used for the RFI pulses corresponds to a minimum EIRP of 20 dBW, which corresponds to the worst-case situation occurring when the Shuttle is exactly on the line-of-sight from the TDRS to the RFI region.

The results are given in Table 7. They apply to the high and low carrier frequency (note, however, that the environments apply only to one of the carrier frequencies as denoted by the second character of their abbreviations. Using the EH or WH environment in conjunction with the low carrier frequency is, therefore,

Table 7. RFI DEGRADATION PREDICTIONS.

BIT RATE	RFI ENVIRONMENT	PULSE DURATION	DEGRADATION (dB)
96E3	EH	2 μsec	0.794
		5 μsec	2.283
	EL	2 μsec	1.770
		5 μsec	6.405
	WH	2 μsec	0.255
		5 μsec	0.749
	WL	2 μsec	0.487
		5 μsec	1.446
192E3	EH	2 μsec	0.921
		5 μsec	2.422
	EL	2 μsec	2.204
		5 μsec	7.461
	WH	2 μsec	0.290
		5 μsec	0.801
	WL	2 μsec	0.582
		5 μsec	1.642

not realistic).

The degradations vary greatly between the environments. The higher data rate increases the degradation slightly, while the longer pulse durations approximately triples (in dB) the degradation. The worst degradation results from environment EL and amounts to 7.5 dB for 5 μsec pulses at the high data rate. This is not surprising, since this environment has a considerably higher pulse rate at the high CW power levels than any other environment.